Amplification of pionic instabilities in high-energy collisions? *

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The possibility of forming disoriented chiral condensates in high-energy collisions has generated considerable research activity in recent years. We have developed a simple and instructive framework for analyzing the conditions for the occurrence of the *DCC* phenomenon.

Enclosing the system in a box, we decompose the $O(4)$ chiral field $\phi = (\sigma, \boldsymbol{\pi})$ into its spatial average $\underline{\phi}(t)$, the order parameter, and the fluctuating remainder $\delta\phi(x,t)$ representing the quasi-particle excitations. A Hartree factorization [1] then yields Klein-Gordon equations,

$$\left[\Box + \mu^2\right] \delta\phi(x,t) = 0 \ , \qquad (1)$$

The associated effective masses are given by

$$\begin{aligned} \mu_\sigma^2 &= \lambda[3\sigma_0^2 + <\delta\phi^2> + 2 <\delta\sigma^2> - v^2] \ , \\ \mu_\pi^2 &= \lambda[\ \sigma_0^2 + <\delta\phi^2> + 2 <\delta\pi_i^2> - v^2] \ , \end{aligned}$$

where the usual non-linear interaction hass been employed, $V = (\lambda/4)(\phi^2 - v^2)^2 - H\sigma$.

Imagine that the system is formed at a high temperature. The field fluctuations are then sufficiently large to ensure $\mu^2 > 0$. The combined effect of expansion and radiation cools the system and the fluctuations thus decrease in the course of time. This reduces μ^2 which allows the order parameter to grow larger, thus counteracting the decrease of the effective masses. The resulting behavior of μ^2 is then a delicate balance: for slow cooling the induced growth of σ_0 is approximately adiabatic and the system relaxes towards the vacuum through metastable configurations. On the other hand, for a sufficiently rapid cooling a compensating growth of the order parameter cannot occur quickly enough and the effective pion mass may turn imaginary, $\mu_\pi^2 < 0$, indicating that the system has entered a regime exhibiting exponential growth of some modes.

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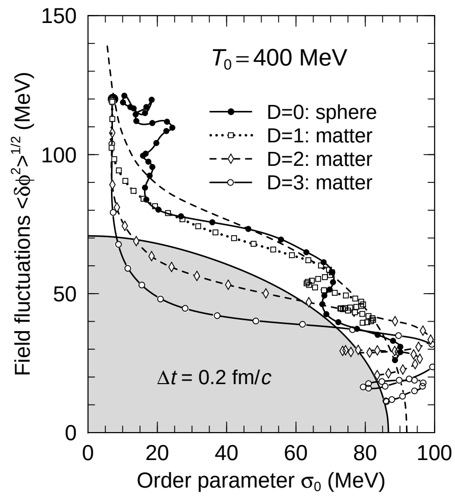

Figure 1: The combined dynamical evolution of the order parameter and the field fluctuations. The dashed curve connects the equilibria and the shaded region is the unstable region within which $\mu_\pi^2 < 0$. The systems start in equilibrium at $T_0 = 400$ MeV. The irregular solid trajectory (D=0) has been obtained by solving the standard equations of motion for a spherical source with R=5 fm. The other three trajectories have been obtained by adding a cooling term emulating expansion in D=1,2,3 dimensions.

The resulting distortion of the pion spectrum can be estimated by a simple WKB method in which the integral of the imaginary frequency yields an amplification factor given by $\exp(G_k)$:

Table 1: Amplification coefficients $G^\pi_{k=0}$.

T_0 (MeV)	$D=1$	$D=2$	$D=3$
200	0.00	0.02	0.11
220	0.00	0.50	0.55
240	0.01	1.20	1.19
300	0.00	1.84	2.06
400	0.00	1.67	2.49
500	0.00	1.31	2.61

[1] J. Randrup, Physical Review D (in press).